Monitoring Beaked Whale Movements During Submarine Commanders Course Using Satellite Telemetry Tags

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LONG-TERM GOALS

This project is focused on the effects of mid-frequency active sonar and, in particular, the effects of the 53C sonar used by the US Navy on deep-diving odontocetes. In response to this concern, satellite telemetry is being used to monitor the movements of beaked whales and other odontocete cetacean species on the US Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) range before, during and after sonar exercises; and to study the movement patterns of odontocetes more widely in the canyons of the northern Bahamas to obtain baseline data on the movement patterns of species that may be encountered on the AUTEC range.

OBJECTIVES

The primary goal of the project is to measure the potential effects of military operations using mid-frequency active sonar on the movements of beaked whales. Specifically, the objectives are:

- To deploy satellite telemetry tags before the May 2009 Submarine Commanders Course (SCC) to track the movements of beaked whales before, during and after the SCC and compare movement patterns with and without the presence of MFA tactical sonars.
- To photo-identify individuals within each beaked whale group to match to an existing catalogue and assess their age and sex classes to determine if movement differs by individual and/or age/sex class and to aid in resighting of tagged animals post-tagging (as a future separate effort).
- To obtain biopsy samples from beaked whales using remote sampling techniques to contribute towards a study of their population structuring, and to examine possible genetic covariates for movement patterns.

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14. ABSTRACT

This project is focused on the effects of mid-frequency active sonar and, in particular, the effects of the 53C sonar used by the US Navy on deep-diving odontocetes. In response to this concern, satellite telemetry is being used to monitor the movements of beaked whales and other odontocete cetacean species on the US Navy?s Atlantic Undersea Test and Evaluation Center (AUTEC) range before, during and after sonar exercises; and to study the movement patterns of odontocetes more widely in the canyons of the northern Bahamas to obtain baseline data on the movement patterns of species that may be encountered on the AUTEC range

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Secondary objectives are:

- To deploy satellite tags, collect biopsy samples and photo-identify non-beaked whale species, including sperm whales, pilot whales, false killer whales and melon-headed whales.

APPROACH

This is a collaborative project between the Bahamas Marine Mammal Research Organisation (BMMRO), the Protected Resources Division of the NOAA Southwest Fisheries Science Center (SWFSC), and the US Naval Undersea Warfare Center (NUWC), with field logistics funded by the Office of Naval Research and tagging funds provided by the NOAA Ocean Acoustics Program. The work was conducted under Bahamian research permit (permit no. 1) issued to the Bahamas Marine Mammal Research Organisation under authorization of the Bahamas Marine Mammal Protection Act 2005 and under the guidance of BMMRO's Institutional Animal Use and Care Committee.

The project was conducted within the AUTEC-Andros Operating Area (Figure 1). An acoustic team from NUWC were on site to operate the Marine Mammal Monitoring on Navy Undersea Ranges tool (M3R). A 6.8 m Novurania rigid-hulled inflatable boat (RHIB) was vectored to animals on the AUTEC range using M3R. The tagging team consisted of four personnel: captain, Diane Claridge (BMMRO); photo-id/data recorder, Charlotte Dunn (BMMRO); biopsy/photo-id, Robert Pitman (SWFSC); and tagger, John Durban (SWFSC). When a group of animals was sighted individuals within the group were photo-identified, and biopsy and tagging attempts were made on sub-adult and adult animals (but not on calves), with the first priority being to deploy satellite tags. When possible, survey effort was focused on finding beaked whales on the AUTEC range; however, surveys were also conducted in the waters of NE and NW Providence Channels when access to the AUTEC range was restricted, or when the sea conditions at AUTEC prevented visual surveys and tagging operations.

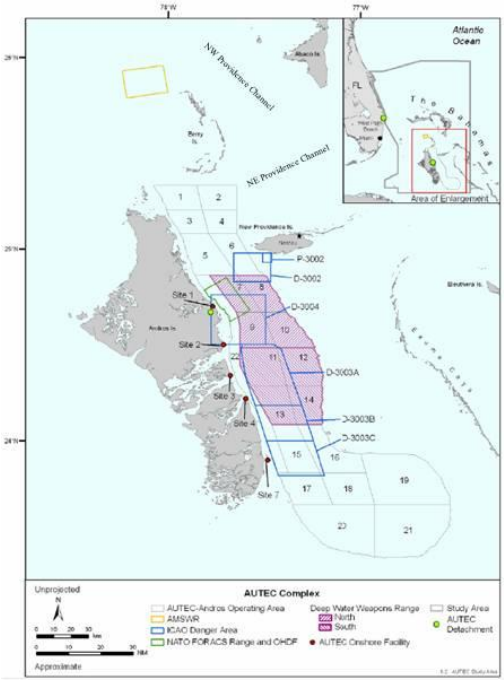

Figure 1. Map of the Andros-AUTEC Operating Areas, also showing NE and NW Providence Channels to the north of the AUTEC range.

The movement of individual whales was monitored by deploying satellite "dart-tags" (e.g. Andrews et al. 2008), with a location-only satellite transmitter (SPOT5 model, Wildlife Computers, Redmond, WA). This small tag was held on the external surface of the whale, ideally near the base of the dorsal fin/hump, by two barbed titanium darts which threaded into the tag and penetrated to a depth of 4.5 cm (Figure 2). Tags were deployed from distances of approximately 8 - 25 m using a black-powder rifle to project the tag on the end of a crossbow bolt, which fell away on contact with the whale.

Figure 2. A satellite dart-tag (shown by arrow) successfully deployed at the base of the dorsal fin of a male Blainville's beaked whale at AUTEC in May 2009.

The tags were scheduled to transmit for six 2-hour periods each calendar day, and transmissions from the tag were recorded and processed using the ARGOS system (http://www.argos-system.org/). Received locations were filtered as described by Freitas et al. (2008) with a maximum swim speed of 3 m s^{-1}. Four of the tags were also programmed to record time-at-temperature data, as a proxy for dive depths. Not all tags were programmed with this capability, due to concern over the increased power-demand on the tags' batteries. Previously collected temperature-at-depth profiles have shown little thermal stratification of the water column in NW or NE Providence Channels during May (BMMRO unpublished data), and therefore temperature shows an approximately linear relationship with depth. The tags were programmed to log and transmit the proportion of 10-second recording intervals in which the tag's internal temperature sensor recorded temperature in 12 temperature bins (<4ºC; >24ºC; and 10 bins of 2ºC increments between 4ºC and 24ºC). Separate temperature histograms were produced for each 6-hour interval (01:00-06:59, 07:00-12:59, 13:00-18:59, 19:00-00:59) during the life of the tag, providing the potential to examine for diurnal differences in dive depths and providing resolution for detecting spatially-linked changes in diving behavior over time.

WORK COMPLETED

The tagging field effort was based from AUTEC (19 – 28 April) and from the R/V *Walton Smith*, operated by the University of Miami (29 April – 24 May 2009). Nine satellite dart-tags were deployed on three species: Blainville's beaked whales (*Mesoplodon densirostris, n* = 3); Cuvier's beaked whales (*Ziphius cavirostris, n* =1); and sperm whales (*Physeter* macrocephalus, n = 5). Transmissions were received from seven of the tags, which transmitted for up to 25 days, and locations were calculated from receptions by the ARGOS satellite system (Table 1).

Table 1. Details of satellite tag deployments. "Tag" number depicts the cumulative tag number for each species: Md = M. densirostris, Zc = Z. cavirostris and Pm = P. macrocephalus. Sex (M = male; F = female) of tagged whales was determined by the size (sperm whales) and presence of erupted teeth and scarring patterns (beaked whales). The total number of locations was determined after filtering location data as described by Freitas et al. (2008), with a maximum swim speed of 3 m s^{-1}. Tags programmed to collect time-at-temperature data are indicated by * next to the tag number.

Tag	Sex	Deployed	Last location	Duration (Days)	Days with locations	Total locations after filter	Placement and attachment
Md1	F	5-May-09	12-May-09	8	7	16	Flank below dorsal fin, flush
Md2*	U	5-May-09	None	0	0	0	Dorsal fin, flush
Md3	M	7-May-09	31-May-09	25	25	103	Anterior insertion of fin, flush
Zc1*	F	6-May-09	20-May-09	15	9	16	Anterior dorsal fin, one dart missed fin
Pm1*	F?	30-Apr-09	1-May-09	2	1	1	Base of dorsal hump, not flush
Pm2	F?	5-May-09	18-May-09	15	15	56	Dorsal hump, flush
Pm3*	F?	5-May-09	15-May-09	12	12	45	Dorsal hump, one dart missed above hump
Pm4	F?	20-May-09	None	0	0	0	Flank below dorsal hump
Pm5	F?	20-May-09	25-May-09	6	6	18	Just below dorsal hump

The locations calculated from tag signals provided valuable baseline information on the scale of movements for these species in this area (Figure 3), including movement data for an adult male Blainville's beaked whale tracked in the area of the AUTEC range before, during and after the SCC.

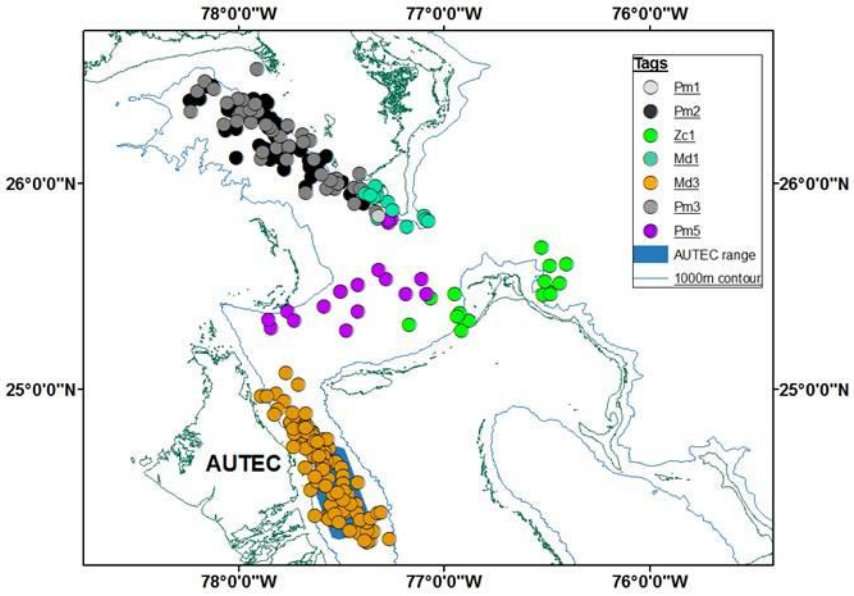

Figure 3. Locations from satellite dart-tags deployed on sperm whales (Pm 1,2,3,5), a Cuvier's beaked whale (Zc1) and Blainville's beaked whales (Md 1,3), 30 April – 31 May 2009.

RESULTS

During this preliminary study, one of our tags (Md3, Table 1; Figure 2) provided 25 days of movement data for an adult male Blainville's beaked whale in the area of the AUTEC range before, during and after an active sonar exercise during the SCC that took place 14-17 May 2009, known as the mini-war. The whale was tagged about 15 km north of the center of the AUTEC range, and during the duration of the tag transmission, the whale moved widely over the AUTEC range and Tongue of the Ocean (Figure 4).

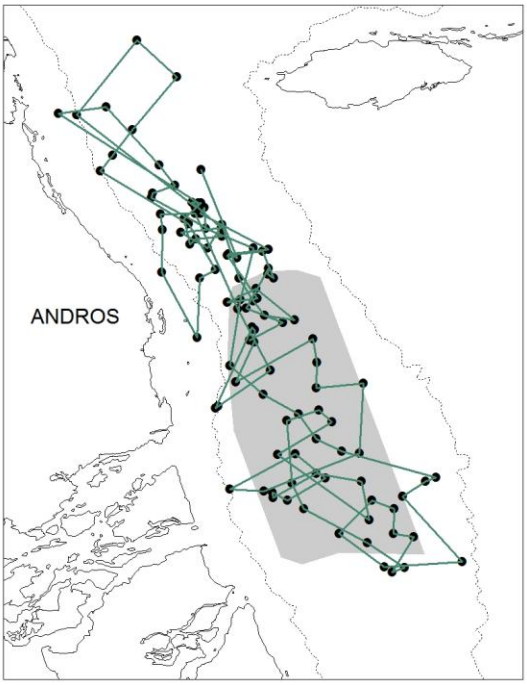

Figure 4. Track (green line between location dots) of a Blainville's beaked whale (Md3) satellite tagged near the AUTEC range in May 2009. The 1000m depth contour is indicated by a broken black line and the shaded area indicates the extent of the hydrophone array of the AUTEC range.

However, there was evidence of differential movement related to the timing of the sonar exercise during the mini-war. During the 72 hours before the sonar exercise started, the mean distance from whale to the center of the AUTEC range was 36.9 km ± 2.9 (s.d.) (Fig. 5 A,E). The mean distance during the 72 hour sonar exercise was 53.9 km ± 9.7 (s.d.) (Fig. 5B, E), and returned to 29.3 km ± 10.7 (s.d.) and 12.8 km ± 4.3 (s.d.) from 0-72 (Fig. 5C, E) and 72-144 hours (Fig. 5D, E) after the exercise stopped.

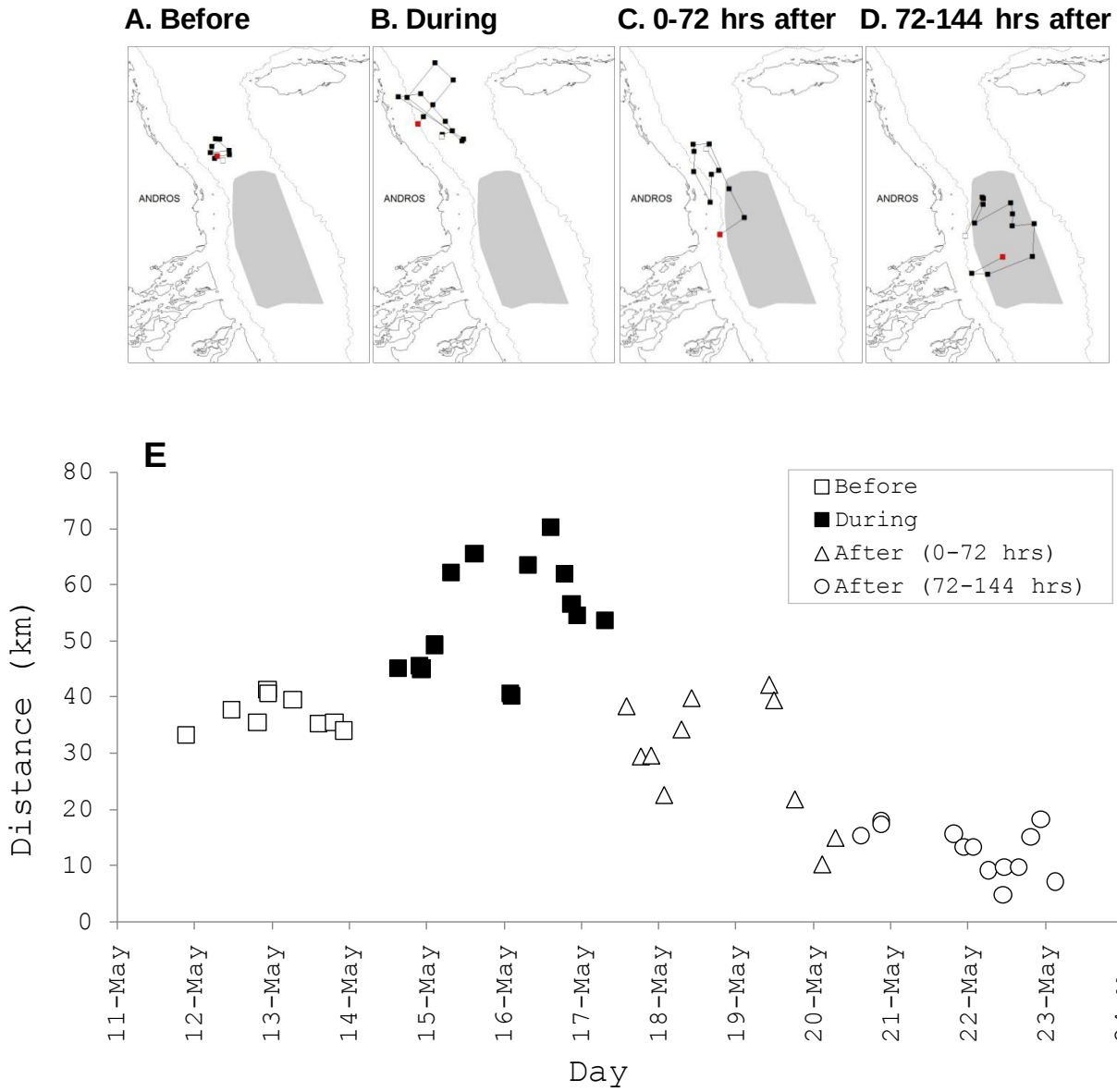

Figure 5. Locations of a Blainville's beaked whale (Md3) satellite tagged near the AUTEC range in May 2009. For each plot (A-D), the starting and ending locations are marked with a white and red square, respectively. The 1000m depth contour is indicated by a broken black line and the shaded area indicates the extent of the hydrophone array of the AUTEC range. A, Locations recorded 72 hours before the onset of a sonar exercise on the AUTEC range. B, Locations recorded during the sonar exercise. C, Locations recorded 72 hours after the end of the exercise. D, Locations recorded between 72 and 144 hours after the end of the exercise. E, Plot of distance from each location to the center of the AUTEC range as a function of date. (Adapted from Tyack et al., in prep.)

Analysis of the time-at-temperature data is not yet complete, however preliminary data exploration has shown this approach to be of considerable utility, at least until satellite-linked TDR tags are available in a small package (Figure 6). For example, an adult female Cuvier's beaked whale (Zc1) spent a greater proportion of time in warmer waters near the surface in the night-time recording periods relative to the day-time periods, implying that surface dives are deeper (colder water) during the day.

These data highlight the ability to use the temperature recording capabilities of the SPOT 5 tag to detect differences in diving behavior. Our data suggest that this capability offers a valuable addition to individual-based monitoring using satellite tags, enabling the detection of spatially-linked changes in the dive behavior of whales that may occur in relation to the timing of sonar exercises.

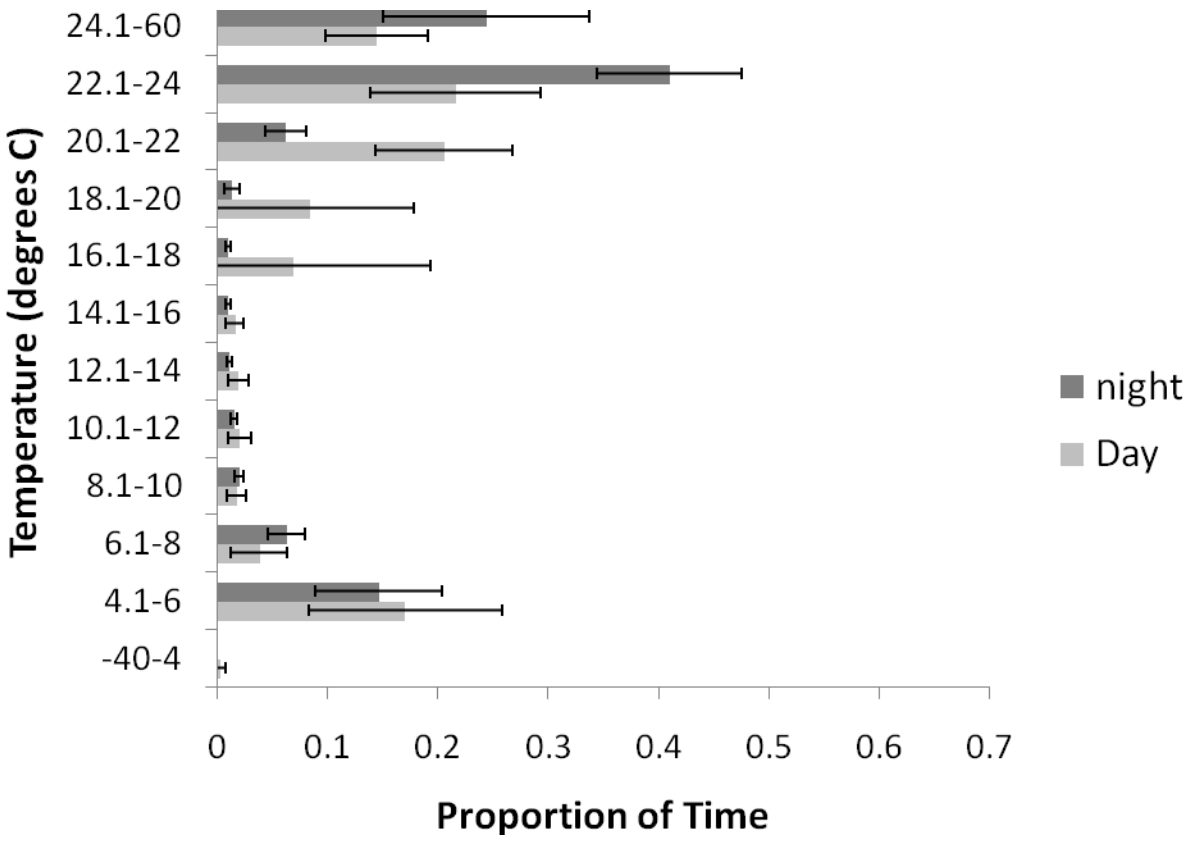

Figure 6. Diving behavior of an adult female Cuvier's beaked whale (Zc1), represented by the proportion of 10-second recording intervals spent in each of 12 temperature bins. The solid bars represent the median values across recording periods, and the lines the range for each temperature bin. This shows a greater proportion of time spent in warmer waters near the surface in the night-time recording periods relative to the day-time periods, implying that surface dives are deeper (colder water) during the day.

IMPACTS/APPLICATIONS

Beaked whales mass strand during some naval sonar exercises, but the cause is unknown (Evans and England, 2001; Cox *et al.* 2006). Acoustic monitoring during multi-day SCC exercises involving tactical mid-frequency sonars has shown that beaked whales stop echolocating and likely move away, with animals only detected near the periphery of the range away from the sonar source. Once the exercises stop, beaked whale detections gradually return to pre-sonar levels in the center of the range over 2-3 days (Moretti *et al.*, submitted). However, the acoustic monitoring cannot directly measure the responses of individual whales to sonar, especially once they have ceased echolocating.

The initial data presented here evidence the potential utility of using satellite-telemetry for individual-based monitoring to measure the response of beaked whales to sonar. These data support the

interpretation based on passive acoustic monitoring that beaked whales swim several tens of kilometers away from sonar exercises and take several days to return after sonar transmissions cease (Tyack *et al.*, in prep.). However, caution must be used in interpreting these data from just a single whale, highlighting the need to obtain further data on individual movements around sonar exercises. Monitoring movements of beaked whales during real sonar events will contribute to the development of effective mitigation measures to lessen impacts during military exercises.

RELATED PROJECTS

The study relates closely to the Behaviour Response Study conducted during 2007 and 2008 at AUTEC and to similar types of studies being conducted on killer whales in Norway. However, this project seeks to expand that effort by monitoring responses of beaked whales to real sonar signals. This project will also provide valuable information on the movement patterns of beaked whales within the Tongue of the Ocean to address questions about their habitat preference, occupancy patterns and population structure.

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